JC540 U.S. PTO
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11/30/98

JC408 U.S. PTO
11/30/98

LAW OFFICES
SUGHRUE, MION, ZINN, MACPEAK & SEAS, PLLC
2100 PENNSYLVANIA AVENUE, N.W.
WASHINGTON, DC 20037-3213
TELEPHONE (202) 293-7060
FACSIMILE (202) 293-7860

CALIFORNIA OFFICE
CAMINO REAL
MENLO PARK, CA 94025
TELEPHONE (650) 325-5800
FACSIMILE (650) 325-6606

JAPAN OFFICE
TOEI NISHI SHIMBASHI BLDG 4F
13-5 NISHI SHIMBASHI 1-CHOME
MINATO-KU, TOKYO 105, JAPAN
TELEPHONE (03) 3503-3760
FACSIMILE (03) 3503-3756

November 30, 1998

BOX PATENT APPLICATION
Assistant Commissioner for Patents
Washington, D.C. 20231

Re: Application of Kimikazu MATSUMOTO, Shinichi NISHIDA and Hideo SHIBAHARA
ACTIVE MATRIX LIQUID-CRYSTAL DISPLAY DEVICE
Our Ref.: Q052513

Dear Sir:

Attached hereto is the application identified above including 32 sheets of the specification, claims, 8 sheets of informal drawings, and executed Declaration and Power of Attorney. The Assignment will be filed at a later date.

The Government filing fee is calculated as follows:

Total claims	7	-	20	=		x	$18.00	=	
Independent claims	5	-	3	=	2	x	$78.00	=	$156.00
Base Fee									$760.00
TOTAL FILING FEE									**$916.00**

A check for the statutory filing fee of $916.00 is attached. You are also directed and authorized to charge or credit any difference or overpayment to Deposit Account No. 19-4880. The Commissioner is hereby authorized to charge any fees under 37 C.F.R. §§ 1.16 and 1.17 and any petitions for extension of time under 37 C.F.R. § 1.136 which may be required during the entire pendency of the application to Deposit Account No. 19-4880. A duplicate copy of this transmittal letter is attached.

Priority is claimed from November 28, 1997 based on Japanese Application No. 328678/97. The priority document will be filed at a later date.

Respectfully submitted,
SUGHRUE, MION, ZINN,
MACPEAK & SEAS, PLLC
Attorneys for Applicant

By: ______________________
J. Frank Osha
Reg. No. 24,625

ACTIVE MATRIX LIQUID-CRYSTAL DISPLAY DEVICE

FIELD OF THE INVENTION

This invention relates to an active matrix liquid-crystal display device intended to prevent the image-sticking defect that a residual image occurs when displaying another image after displaying the same image for a long time.

BACKGROUND OF THE INVENTION

Recently, an IPS (in-plane switching) mode (or horizontal electric field drive type) liquid-crystal display device, whose displaying is conducted by rotating the molecular axis direction (hereinafter referred to as 'director') of oriented liquid-crystal (hereinafter also referred to as 'LC') molecule in parallel direction to the substrate, has been researched and developed.

Such an IPS-mode LC display device does not have view-angle dependency to 'standing direction' of LC molecule because only the short-axis direction is constantly viewed even when shifting its viewpoint. Therefore, it can obtain a wide view angle, compared with an LC display device, such as conventional TN (twist nematic) mode, where electric field is generated in the perpendicular direction of substrates to sandwich an LC layer between the substrates (hereinafter referred to as 'vertical electric field drive type).

In the research and development of the IPS-mode LC display device, various techniques developed in the vertical electric field drive type devices are diverted and applied. However, the

techniques of vertical electric field drive type devices cannot be unalteredly diverted thereto, particularly, as to view-angle characteristic and reliability, by the following reasons.

For example, with reference to normally-black LC display device, the comparison between TN mode as an example of the vertical electric field drive type and IPS mode intended for this invention will be explained.

In TN mode, directors are generally twisted by 90° between two substrates in zero field, but they are existing in a plane parallel to the plane of substrate, like the case of IPS mode. However, in applying electric field, all directors are normally oriented in a plane parallel to the surface of substrate in IPS mode whereas all directors are normally oriented perpendicularly to the surface of substrate in TN mode.

Therefore, in IPS mode, the display appears to be white even when viewing from any viewpoint, but, in TN mode, it appears to be white or gray, as neutral color, depending on the viewing directions due to the refractive-index difference between the short axis and long axis of LC molecule. As understood from this, IPS mode and TN mode have no view-angle characteristic obtained resultantly in common, due to the difference in driving system.

Also, with respect to unit pixel composition, in TN mode, electrodes to compose a pixel are formed on two substrates, respectively because the electric field is generated perpendicularly to the plane of substrate, but, in IPS mode, all electrodes to compose a pixel are formed only on one substrate because the electric field is generated parallel to the plane of

substrate. Namely, in TN mode, electric flux line to drive LC does not penetrate through the color layer of color filter, but, in IPS mode, electric flux line to drive LC penetrates through the color layer of color filter. Viewing from this, it is obvious that the degree of the influence of color layer of color filter to LC panel characteristic is different between TN mode and IPS mode.

From the differences described above, it is evident that the conventional techniques of TN cannot be unalteredly diverted to IPS.

FIGS.1 and 2 are a cross sectional view and a top view, respectively, showing illustratively the basic composition of a conventional active matrix LC display device using horizontal electric field driving. Referring to FIG.1, in this conventional LC display device, electrodes to compose a pixel electrode are formed only on one substrate 112 of two substrates sandwiching an LC layer 101 confined, on an opposing substrate 102 no electrode is formed and only a color filter to color light transmitted therethrough is formed.

Namely, on the electrode-forming substrate 112, one active element (not shown in FIG.1), one drain signal electrode 103, one gate signal electrode (not shown in FIG.1), and pairs of pixel electrodes (pixel electrodes 104 and common electrodes 105) are disposed in unit pixel. All formed on the color filter forming substrate 102 are color filter layers (Red 109, Green 110, Blue 111) to color light transmitted through LC into a specific color, generally red, green or blue, and a black matrix layer 108 to shield

leakage light from the neighborhood of the drain signal electrode 103 on the electrode-forming substrate 112 or the gate signal electrode.

The color layers (R, G, B) 109, 110, 111 are formed considering the color purity and chromaticity level of light transmitted through panel. The color layers (R, G, B) 109, 110, 111 are produced by coloring an organic polymer material, such as polyvinyl alcohol or acryl resin, by using a dyestuff or pigment. Therefore, when producing it by, e.g., pigment scattering, the dielectric constants of the color layers (R, G, B) 109, 110, 111 vary, depending on the kind of pigment or the scattering density. Though the thickness H of color layer is set to be greater than 1μm so as to enhance the color purity, the respective thicknesses of the color layers (R, G, B) 109, 110, 111 are also different each other because the respective transmissivities of the color layers (R, G, B) 109, 110, 111 are different each other. Accordingly, the color-layer static capacitance of color layer represented by the product of color-layer dielectric constant and color-layer thickness H is not constant in the color layers (R, G, B) 109, 110, 111 each.

In the arrangement of respective electrodes within unit pixel, the common electrode 105 is located just nearby the drain signal electrode 103, the pixel electrodes 104 are disposed at certain intervals, the common electrode 105 and pixel electrode 104 are alternately disposed at equal intervals or unequal intervals, the common electrode 105 is further located in a layer covered with interlayer insulating film 106 nearby the substrate, different

from the scanning signal electrode 103 and pixel electrode 104 (the common electrode 105 and pixel electrode 104 each are located in the separate layer).

Also, the active matrix LC display device uses AC drive to prevent the deterioration of panel members such as LC. For example, the polarity of signal is inverted every one field with a reference level (opposing electrode's level) at the center.

Also, in the active matrix LC display device, a drain voltage applied when the TFT element is turned on shifts by V_P in the minus-potential direction of gate voltage when the TFT element is turned off, thereby causing a certain amount of potential fall. Namely, being up and down asymmetrical to the reference level and opposing electrode's level, resultantly V_P (hereinafter referred to as 'fieldthrough') is applied to the LC drive voltage as a DC component. When the DC component is applied to the LC drive voltage, the accumulation of charge occurs, therefore causing an image-sticking defect etc.

Such a phenomenon that the DC component is applied to the LC drive voltage may occur in TN type where electric field is applied perpendicularly to the substrate. Its solution is disclosed in Japanese patent application laid-open No.61-116392 (1986).

In this application, it is proposed that DC voltage applied to LC is corrected by adding a predetermined potential difference (V_T) to a reference level of AC drive signal. Namely, V_P - V_T is given to be up and down symmetrical to the reference level.

However, LC capacitance C_{LC}, which varies due to the

orientation state of LC (degree of inclination of LC molecule to pixel electrode), generally differs in each pixel. The relationship between this capacitance C_{LC} and a potential fall difference ΔV_p of LC charging voltage when gate voltage is turned off is given by expression 1, which is reported by T. Yanagisawa et al., "Japan Display '86", p.192:

$$\Delta V_P = -\frac{C_{GS}}{C_{GS}+C_{LC}}\cdot(V_{ON}-V_{OFF})............[1]$$

In this regard, Japanese patent application laid-open No.5-72997 (1993) describes that the image-sticking defect becomes most unlikely to happen by setting C_{LC} of B, a minimum capacitance value when the amplitude of LC drive voltage is small, i.e., when LC is oriented parallel to pixel electrode. This is because the accumulation of charge added to drive voltage by DC component becomes large as the drain voltage increases.

Meanwhile, the fieldthrough is caused by parasitic capacitance C_{GS} between gate and source of TFT element, and by that the respective charges accumulated in LC capacitance C_{LC} and accumulation capacitance C_{GS} when the gate pulse becomes ON are redistributed to the respective capacitance when the gate pulse becomes OFF. In TN type, on the side of opposing electrode a transparent electrode (opposing electrode) is formed on the color layer, therefore electric field generated by the pixel electrode and opposing electrode does not penetrate through the inside of the color layer and the color layer itself is polarized.

Therefore, as shown in expression 1, the item of color layer is not included in the fieldthrough ΔV_P.

In contrast with this, in horizontal electric field drive type, the transparent electrode on the color filter forming substrate in TN type does not exist, therefore the electric flux line generated by the pixel electrode and common electrode penetrates through the inside of the color layer. Namely, the fieldthrough ΔV_P is a function of color-layer capacitance C_{COLOR}, which is given by:

$$\Delta V_P = -\frac{C_{GS}}{C_{GS} + C_{LC} + C_{COLOR}} \cdot (V_{ON} - V_{OFF}) \ldots\ldots\ldots\ldots [2]$$

Also, the color layers (R, G, B) of color filter are formed considering the color purity and chromaticity level of light transmitted through panel. The color layers (R, G, B) are produced by coloring an organic polymer material, such as polyvinyl alcohol or acryl resin, by using a dyestuff or pigment. Therefore, when producing it by, e.g., pigment scattering, the dielectric constants of the color layers (R, G, B) vary, depending on the kind of pigment or the scattering density. Though the thickness H of color layer is set to be greater than 1μm so as to enhance the color purity, the respective thicknesses of the color layers (R, G, B) are also different each other because the respective transmissivities of the color layers (R, G, B) are different each other. Accordingly, the color-layer static capacitance represented by the product of color-layer dielectric

constant and color-layer thickness H is not constant in the color layers (R, G, B) each.

When a same voltage is applied to the color layers (R, G, B) with such characteristics, the fieldthrough ΔV_p results in differing in the color layers (R, G, B) each because the LC static capacitance and the static capacitance of the color layers (R, G, B) are different each other. Namely, different DC components are applied to LC as to the color layers (R ~ B) each, the accumulation of charge occurs within the panel, thereby causing the image-sticking defect that a residual image occurs when displaying another image after displaying the same image for a long time.

On the other hand, Japanese patent application laid-open No.2-211402 (1990) discloses a technique to control the thickness and dielectric constant of color layers (R, G, B). This is devised to get correspondence in optical response of the color layers (R, G, B) each, and relates to TN type where the color layer is formed on the transparent electrode. Therefore, its electrode structure and application of electric field are clearly different from those of this invention.

As described above, in the conventional techniques, there is the problem that different DC components are added to LC drive voltage as to the color layers (R, G, B) each, thereby causing the image-sticking defect. This is caused directly by that, in the horizontal electric field drive type active matrix LC display device, electric flux line to drive LC penetrates through the inside of the color layers (R, G, B) because the transparent

electrode does not exist on the color filter forming substrate, and that the color layer itself is therefore polarized due to the difference in sum of color-layer static capacitance and LC static capacitance.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the invention to provide an active matrix liquid-crystal display device by which the image-sticking defect that a residual image occurs when displaying another image after displaying the same image for a long time can be effectively prevented.

According to the invention, an active matrix liquid-crystal display device, comprises:

an electrode-formed substrate which is composed of a drain signal electrode, a gate signal electrode, a pixel electrode and a common electrode to compose a pixel unit, and an active element;

a color-filter-formed substrate where no electrode is formed and a color filter layer of red (R), green (G) and blue (B) to color light transmitted therethrough is formed; and

a liquid-crystal layer sandwiched between the electrode-formed substrate and the color-filter-formed substrate;

wherein a plurality of the pixel electrode and the common electrode on the electrode-formed substrate each are in unit pixel, and disposed parallel at predetermined intervals and alternately in a same layer or through insulating film, electric field substantially parallel to the electrode-formed substrate and the color-filter-formed substrate is applied to the liquid-crystal

layer by applying an alternating-current voltage between the pixel electrode and the common electrode, the pixel electrode and the common electrode are connected to an external control means by which the applied electric field is arbitrarily controlled according to a display pattern, two orientation films print-coated are formed directly or through insulating film on the electrode-formed substrate and the color-filter-formed substrate, respectively, the two orientation films are disposed opposite each other and with a predetermined clearance by a panel spacer, nematic liquid crystal is filled into the clearance while being anti-parallel oriented, and fieldthrough of respective color layers (R,G,B) of the color filter layer is equalized.

According to another aspect of the invention, an active matrix liquid-crystal display device, comprises:

an electrode-formed substrate which is composed of a drain signal electrode, a gate signal electrode, a pixel electrode and a common electrode to compose a pixel unit, and an active element;

a color-filter-formed substrate where no electrode is formed and a color filter layer of red (R), green (G) and blue (B) to color light transmitted therethrough is formed; and

a liquid-crystal layer sandwiched between the electrode-formed substrate and the color-filter-formed substrate;

wherein a plurality of the pixel electrode and the common electrode on the electrode-formed substrate each are in unit pixel, and disposed parallel at predetermined intervals and alternately in a same layer or through insulating film, electric field substantially parallel to the electrode-formed substrate and the

color-filter-formed substrate is applied to the liquid-crystal layer by applying an alternating-current voltage between the pixel electrode and the common electrode, the pixel electrode and the common electrode are connected to an external control means by which the applied electric field is arbitrarily controlled according to a display pattern, two orientation films print-coated are formed directly or through insulating film on the electrode-formed substrate and the color-filter-formed substrate, respectively, the two orientation films are disposed opposite each other and with a predetermined clearance by a panel spacer, nematic liquid crystal is filled into the clearance while being anti-parallel oriented, and the product $\varepsilon \times H$ of the dielectric constant ε and thickness H of respective color layers (R, G, B) of the color filter layer is equalized.

According to another aspect of the invention, an active matrix liquid-crystal display device, comprises:

an electrode-formed substrate which is composed of a drain signal electrode, a gate signal electrode, a pixel electrode and a common electrode to compose a pixel unit, and an active element;

a color-filter-formed substrate where no electrode is formed and a color filter layer of red (R), green (G) and blue (B) to color light transmitted therethrough is formed; and

a liquid-crystal layer sandwiched between the electrode-formed substrate and the color-filter-formed substrate;

wherein a plurality of the pixel electrode and the common electrode on the electrode-formed substrate each are in unit pixel, and disposed parallel at predetermined intervals and alternately

in a same layer or through insulating film, electric field substantially parallel to the electrode-formed substrate and the color-filter-formed substrate is applied to the liquid-crystal layer by applying an alternating-current voltage between the pixel electrode and the common electrode, the pixel electrode and the common electrode are connected to an external control means by which the applied electric field is arbitrarily controlled according to a display pattern, two orientation films print-coated are formed directly or through insulating film on the electrode-formed substrate and the color-filter-formed substrate, respectively, the two orientation films are disposed opposite each other and with a predetermined clearance by a panel spacer, nematic liquid crystal is filled into the clearance while being anti-parallel oriented, and the active-element-side holding capacitance is varied to each of the color layers so as to compensate a difference in the sum of color-layer capacitance and liquid-crystal capacitance at each of the color layers (R, G, B) in the color filter.

According to another aspect of the invention, an active matrix liquid-crystal display device, comprises:

an electrode-formed substrate which is composed of a drain signal electrode, a gate signal electrode, a pixel electrode and a common electrode to compose a pixel unit, and an active element;

a color-filter-formed substrate where no electrode is formed and a color filter layer of red (R), green (G) and blue (B) to color light transmitted therethrough is formed; and

a liquid-crystal layer sandwiched between the electrode-

formed substrate and the color-filter-formed substrate;

wherein a plurality of the pixel electrode and the common electrode on the electrode-formed substrate each are in unit pixel, and disposed parallel at predetermined intervals and alternately in a same layer or through insulating film, electric field substantially parallel to the electrode-formed substrate and the color-filter-formed substrate is applied to the liquid-crystal layer by applying an alternating-current voltage between the pixel electrode and the common electrode, the pixel electrode and the common electrode are connected to an external control means by which the applied electric field is arbitrarily controlled according to a display pattern, two orientation films print-coated are formed directly or through insulating film on the electrode-formed substrate and the color-filter-formed substrate, respectively, the two orientation films are disposed opposite each other and with a predetermined clearance by a panel spacer, nematic liquid crystal is filled into the clearance while being anti-parallel oriented, and a circuit to send electrical signal to each of the color layers (R, G, B) in the color filter is provided to make a difference in the central value of drain signal voltages for the respective color layers.

According to another aspect of the invention, an active matrix liquid-crystal display device, comprises:

an electrode-formed substrate which is composed of a drain signal electrode, a gate signal electrode, a pixel electrode and a common electrode to compose a pixel unit, and an active element;

a color-filter-formed substrate where no electrode is formed

and a color filter layer of red (R), green (G) and blue (B) to color light transmitted therethrough is formed; and

a liquid-crystal layer sandwiched between the electrode-formed substrate and the color-filter-formed substrate;

wherein a plurality of the pixel electrode and the common electrode on the electrode-formed substrate each are in unit pixel, and disposed parallel at predetermined intervals and alternately in a same layer or through insulating film, electric field substantially parallel to the electrode-formed substrate and the color-filter-formed substrate is applied to the liquid-crystal layer by applying an alternating-current voltage between the pixel electrode and the common electrode, the pixel electrode and the common electrode are connected to an external control means by which the applied electric field is arbitrarily controlled according to a display pattern, two orientation films print-coated are formed directly or through insulating film on the electrode-formed substrate and the color-filter-formed substrate, respectively, the two orientation films are disposed opposite each other and with a predetermined clearance by a panel spacer, nematic liquid crystal is filled into the clearance while being anti-parallel oriented, and a circuit to send electrical signal to each of the color layers (R, G, B) in the color filter is provided to make a difference in the amplitude of drain signal voltages for the respective color layers.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be explained in more detail in conjunction

with the appended drawings, wherein:

FIG.1 is a cross sectional view showing the conventional horizontal electric field drive type liquid-crystal display device,

FIG.2 is a top view showing the conventional horizontal electric field drive type liquid-crystal display device,

FIG.3 is a cross sectional view showing an active matrix liquid-crystal display device in a first preferred embodiment according to the invention where (color-layer static capacitance + LC static capacitance) is equalized in the respective color layers of a color filter,

FIG.4 is a circuit diagram showing an equivalent circuit in an active matrix liquid-crystal display device in a second preferred embodiment according to the invention where TFT-side holding capacitance is varied at each of color layers so as to compensate a difference in the sum of color-layer capacitance and LC capacitance at each of the color layers of a color filter,

FIG.5 is an illustrative diagram showing an example of different central values of drain voltage input to each of the color layers of a color filter in a third preferred embodiment according to the invention,

FIG.6 is a graph showing the relationship between (ε)x(H) of respective color layers and image-sticking defect in the first embodiment,

FIG.7 is an illustrative diagram showing generated fieldthrough and correction amount of drain voltage, and

FIG.8 is a graph showing the relationship between the

correction amount of drain voltage at respective color layers of the color filter in the third embodiment and the image-sticking defect level.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The preferred embodiments of this invention will be explained below, referring to the drawings.

In a horizontal electric field drive type active matrix LC display device in the first preferred embodiment of the invention, as shown in FIG.3, electrodes to compose a pixel electrode are formed only on one substrate 112 of two substrates sandwiching an LC layer 101 confined, on an opposing substrate 102 no electrode is formed and only a color filter to color light transmitted therethrough is formed.

Namely, as shown in FIG.3, on the electrode-forming substrate 112, one active element (TFT element)(not shown in FIG.3), one drain signal electrode 103, one gate signal electrode (not shown in FIG.3), and pairs of pixel electrodes (pixel electrodes 104 and common electrodes 105) are disposed in unit pixel. All formed on the color filter forming substrate 102 are color filter layers (Red 109, Green 110, Blue 111) to color light transmitted through LC into a specific color, generally red, green or blue, and a black matrix layer 108 to shield leakage light from the neighborhood of the drain signal electrode 103 on the electrode-forming substrate 112 or the gate signal electrode.

In the arrangement of respective electrodes within unit pixel, the common electrode 105 is located just nearby the drain signal

electrode 103, the pixel electrodes 104 are disposed at certain intervals, the common electrode 105 and pixel electrode 104 are alternately disposed at equal intervals or unequal intervals, the common electrode 105 is further located in a layer covered with interlayer insulating film 106 nearby the substrate, different from the scanning signal electrode 103 and pixel electrode 104 (the common electrode 105 and pixel electrode 104 each are located in the separate layer).

Also, in order to equalize the sum of the static capacitance of the color layers (R, G, B) 109, 110, 111 and the static capacitance of LC, the color-layer static capacitance in the color layers (R, G, B) 109, 110, 111 each is made to be constant by equalize the product of dielectric constant ε and thickness H in each of the color layers (R, G, B) 109, 110, 111 formed on the color filter forming substrate 102, i.e., by effecting the relation of: ε (RED) x H(RED) = ε (GREEN) x H(GREEN) = ε (BLUE) x H(BLUE) =A.

Therefore, by inputting a drain signal common to the color layers (R, G, B) 109, 110, 111 as shown in FIG.4, the fieldthrough ΔV_p occurred can be equal at each of the color layers (R, G, B) 109, 110, 111, thereby preventing the image-sticking defect.

In the second preferred embodiment of the invention, the holding capacitance of TFT element 305 is varied. The holding capacitance means a capacitance line for the overlapping or capacitance-holding between the pixel electrode 104 and gate electrode. FIG.4 is an equivalent circuit of horizontal electric field drive type panel. The fieldthrough ΔV_p of each of the color

layers (R, G, B) 109, 110, 111 is made to be constant by varying holding capacitance's 301, 306, 308 according to differences of static capacitance among the color layers (R, G, B) 109, 110, 111 while leaving the color-layer static capacitance of the color layers (R, G, B) 109, 110, 111 each different. Thereby the image-sticking defect can be prevented. Meanwhile, 302 is (LC capacitance C_{LC}+ red-layer capacitance C_R), 307 is (LC capacitance C_{LC}+ green-layer capacitance C_G), 309 is (LC capacitance C_{LC}+ blue-layer capacitance C_B).

In the third preferred embodiment of the invention, the central value of drain voltage differs among the color layers (R, G, B) 109, 110, 111. FIG.5 is an illustrative diagram showing kinds of color layer along the abscissa axis and central values V_D of drain voltage to be input to the respective color layers (R, G, B) 109, 110, 111 along the ordinate axis. In this embodiment, the fieldthrough ΔV_P is corrected by means of drive voltage, while leaving the color-layer static capacitance of the color layers (R, G, B) 109, 110, 111 each different and without changing the holding capacitance's 301, 306, 308 of TFT element 305. Namely, the central values V_D of drain voltage are shifted by different fieldthrough ΔV_P generated at the respective color layers (R, G, B) 109, 110, 111. Thereby the image-sticking defect can be prevented.

In the fourth preferred embodiment of the invention, the amplitude of drain voltage differs among the color layers (R, G, B) 109, 110, 111. In this embodiment, the fieldthrough ΔV_P is corrected by means of drive voltage, while leaving the color-

layer static capacitance of the color layers (R, G, B) 109, 110, 111 each different and without changing the holding capacitance's 301, 306, 308 of TFT element 305. Namely, the amplitudes of drain voltage are shifted by different fieldthrough ΔV_p generated at the respective color layers (R, G, B) 109, 110, 111. Thereby the image-sticking defect can be prevented.

Next, the above embodiments of the invention will be detailed with specific values as to its composition and structure.

FIG.3 is a cross sectional view illustratively showing the panel in the embodiments of the invention. In principal part of the process of making the LC display device, particularly, the color filter, patterning polyimide with ultraviolet-sensitive group where less than 1μm pigment of red, green or blue is well dispersed and mixed by using photolithography, then baking it at 230°C for one hour, the color filter layers, i.e., the color layers (R, G, B) 109, 110, 111 are formed on no-alkali glass substrate 102.

The resistivity of the respective color layers (R, G, B) 109, 110, 111 in the embodiments of the invention is, nearly constant, of 0.85 to 1.6x10^{11}(Ωcm), and their specific dielectric constants ε are R=3.4, G=3.6 and B=4.2. The thickness H of the color layers (R, G, B) 109, 110, 111 each is made to be greater than 1.0μm to obtain a sufficient color purity. Samples each differing by 0.1μm in the range of color-layer film thickness level shown in Table 1 are prepared.

The specific samples are of R=1.5μm, G=1.4 to 1.5μm, B=1.2 to 1.5 μm. Also, according to need, inorganic or organic

transparent protective film is formed on the respective color layers (R, G, B) 109, 110, 111 so as to flatten the gap and enhance the etching characteristic.

Table 1

Color layer	ε	H [μm]	Color-layer static capacitance [ε]·[H]
R	3.4	1.5	5.10
G	3.6	1.4 to 1.7	5.04 to 6.12
B	4.2	1.2 to 1.5	5.04 to 6.30

The opposing substrate (color layer forming substrate) on which the color filter made as above-mentioned is formed and the electrode forming substrate on which the active matrix element is formed are coated with orientation film, then the rubbing is conducted in 15° -inclined direction to the longitudinal direction of electrode. In this process, the rubbing density as rubbing strength is controlled to be about 150cm. Then, spraying spacer to get a constant cell thickness, bonding both the substrates, filling LC into the clearance, thereby the active matrix LC display panel is formed.

The thus-made active matrix LC display panels with composition elements of 640x480xRGB where, as shown in Table 1, the thickness of the respective color layers (R, G, B) 109, 110, 111 is varied are rendered to the image-sticking defect test, where in this electro-optic device a checker-flag pattern to alternately display white-display part and black-display part is displayed for a certain time and then changed into halftone display. The

test results are as shown in FIG.6. When the product of color-layer specific dielectric constant ε and color-layer thickness H is equal in all the color layers (R, G, B) 109, 110, 111, the image-sticking defect can be prevented.

Namely, this is when ε (RED) x H(RED) = ε (GREEN) x H(GREEN) = ε (BLUE) x H(BLUE) =A is satisfied. In the first embodiment, A=5.10[μm] is obtained.

Also in the second embodiment where the holding capacitance's 301, 306, 308 are varied to the color layers (R, G, B) 109, 110, 111, respectively, to equalize the fieldthrough ΔV_p generated at the respective color layers (R, G, B) 109, 110, 111 is apparently effective.

Though the first and second embodiments use the technique to equalize the fieldthrough ΔV_p generated at the respective color layers (R, G, B) 109, 110, 111 so as to prevent the image-sticking defect, in the third embodiment the different fieldthrough ΔV_p at the respective color layers (R, G, B) 109, 110, 111 is corrected by means of drive voltage to prevent the image-sticking defect. In the horizontal electric field drive type, the transparent electrode on the color filter forming substrate 102 in TN type does not exist, therefore the electric flux line generated by the pixel electrode 104 and common electrode 105 penetrates through the inside of the color layers (R, G, B) 109, 110, 111. Namely, the fieldthrough ΔV_p is a function of color-layer capacitance C_{COLOR}, which is given by:

$$\Delta V_P = -\frac{C_{GS}}{C_{GS} + C_{LC} + C_{COLOR}} \cdot (V_{ON} - V_{OFF}) \text{............[3]}$$

Now, provided that the specific dielectric constants ε of the respective color layers (R, G, B) 109, 110, 111 are R=3.4, G=3.6 and B=4.2 and the thickness of the color layers (R, G, B) 109, 110, 111 is all 1.5μm, the fieldthrough ΔV_p generated at the respective color layers (R, G, B) 109, 110, 111 given by expression 3 is different each other, and the amount of correction, V_T shown in FIG.7 differs in the color layers (R, G, B) 109, 110, 111 each.

FIG.8 shows the relationship between amount drain correction and image-sticking defect level at the respective color layers (R, G, B) 109, 110, 111 in the case where a LC display device is built using this color filter. From this, it will be understood that the correction amount of drain voltages V_1, V_2, V_3 to give the lowest image-sticking defect level is different each other. Namely, it is found that when DC component of 0V to the color layer (R) 109, 0.1V to the color layer (G) 110, and 0.2V to the color layer (B) 111, as amount of correction, is given to shift the central value V_D of the drain voltages V_1, V_2, V_3 each, the image-sticking defect can be best improved. Accordingly, the relationship among V_{BLUE}, V_{RED} and V_{GREEN} which are the central values of drain voltage of blue, red and green, respectively is given by:

$$V_{BLUE}\ (V) = V_{RED}\ (V) - 0.2\ (V) = V_{GREEN} - 0.1\ (V) \quad \text{.....................} [4]$$

Also, in the respective color layers (R, G, B) 109, 110, 111 prepared as shown in Table 1, the resistivity Y (Ω·cm) of the color layers (R, G, B) 109, 110, 111 is laid along the abscissa axis,

and the correction amount X (V) of central value of drain voltage in each of the color layers (R, G, B) 109, 110, 111 most effective to prevent the image-sticking defect is laid along the ordinate axis. Found in this case is the relationship between X and Y given by:

$$Y = C \cdot X + D \text{ ....} [5]$$

where C and D are in the range of:

$$3 \times 10^{11} < C < 7 \times 10^{11}$$

$$0.5 \times 10^{11} < D < 1.0 \times 10^{11}$$

, and typically,

$$C = 5 \times 10^{11}$$

$$D = 0.8 \times 10^{11}$$

Accordingly, by the combination of drive voltage and color layers (R, G, B) 109, 110, 111 to satisfy expression 4 or 5, the image-sticking defect can be improved.

Also in the fourth embodiment where the amplitude of the drain voltages V_1, V_2, V_3 109, 110, 111 of the color layers (R, G, B) 109, 110, 111, respectively is varied, to equalize the fieldthrough ΔV_p generated at the respective color layers (R, G, B) 109, 110, 111 is apparently effective.

Advantages of the Invention:

As explained above, according to the invention, by equalizing the fieldthrough at the respective color layers (R, G, B), the image-sticking defect can be significantly improved.

Also, according to the invention, by equalizing the product of dielectric constant ε and thickness H in each of the color layers

(R, G, B) in the color filter, the image-sticking defect can be significantly improved.

Also, according to the invention, by varying the TFT-side holding capacitance to each of the color layers so as to compensate a difference in the sum of color-layer capacitance and LC capacitance at each of the color layers (R, G, B) in the color filter, the image-sticking defect can be significantly improved.

Also, according to the invention, by providing the circuit to send electrical signal to each of the color layers (R, G, B) in the color filter and making a difference in the central value of drain signal voltages for the respective color layers, the image-sticking defect can be significantly improved.

Although the invention has been described with respect to specific embodiment for complete and clear disclosure, the appended claims are not to be thus limited but are to be construed as embodying all modification and alternative constructions that may be occurred to one skilled in the art which fairly fall within the basic teaching here is set forth.

What is claimed is:

1. An active matrix liquid-crystal display device, comprising:

an electrode-formed substrate which is composed of a drain signal electrode, a gate signal electrode, a pixel electrode and a common electrode to compose a pixel unit, and an active element;

a color-filter-formed substrate where no electrode is formed and a color filter layer of red (R), green (G) and blue (B) to color light transmitted therethrough is formed; and

a liquid-crystal layer sandwiched between said electrode-formed substrate and said color-filter-formed substrate;

wherein a plurality of said pixel electrode and said common electrode on said electrode-formed substrate each are in unit pixel, and disposed parallel at predetermined intervals and alternately in a same layer or through insulating film, electric field substantially parallel to said electrode-formed substrate and said color-filter-formed substrate is applied to said liquid-crystal layer by applying an alternating-current voltage between said pixel electrode and said common electrode, said pixel electrode and said common electrode are connected to an external control means by which the applied electric field is arbitrarily controlled according to a display pattern, two orientation films print-coated are formed directly or through insulating film on said electrode-formed substrate and said color-filter-formed substrate, respectively, the two orientation films are disposed

opposite each other and with a predetermined clearance by a panel spacer, nematic liquid crystal is filled into said clearance while being anti-parallel oriented, and fieldthrough of respective color layers (R,G,B) of said color filter layer is equalized.

2. An active matrix liquid-crystal display device, comprising:

an electrode-formed substrate which is composed of a drain signal electrode, a gate signal electrode, a pixel electrode and a common electrode to compose a pixel unit, and an active element;

a color-filter-formed substrate where no electrode is formed and a color filter layer of red (R), green (G) and blue (B) to color light transmitted therethrough is formed; and

a liquid-crystal layer sandwiched between said electrode-formed substrate and said color-filter-formed substrate;

wherein a plurality of said pixel electrode and said common electrode on said electrode-formed substrate each are in unit pixel, and disposed parallel at predetermined intervals and alternately in a same layer or through insulating film, electric field substantially parallel to said electrode-formed substrate and said color-filter-formed substrate is applied to said liquid-crystal layer by applying an alternating-current voltage between said pixel electrode and said common electrode, said pixel electrode and said common electrode are connected to an external control means by which the applied electric field is arbitrarily controlled according to a display pattern, two orientation films

print-coated are formed directly or through insulating film on said electrode-formed substrate and said color-filter-formed substrate, respectively, the two orientation films are disposed opposite each other and with a predetermined clearance by a panel spacer, nematic liquid crystal is filled into said clearance while being anti-parallel oriented, and the product $\varepsilon \times H$ of the dielectric constant ε and thickness H of respective color layers (R,G,B) of said color filter layer is equalized.

3. An active matrix liquid-crystal display device, comprising:

an electrode-formed substrate which is composed of a drain signal electrode, a gate signal electrode, a pixel electrode and a common electrode to compose a pixel unit, and an active element;

a color-filter-formed substrate where no electrode is formed and a color filter layer of red (R), green (G) and blue (B) to color light transmitted therethrough is formed; and

a liquid-crystal layer sandwiched between said electrode-formed substrate and said color-filter-formed substrate;

wherein a plurality of said pixel electrode and said common electrode on said electrode-formed substrate each are in unit pixel, and disposed parallel at predetermined intervals and alternately in a same layer or through insulating film, electric field substantially parallel to said electrode-formed substrate and said color-filter-formed substrate is applied to said liquid-crystal layer by applying an alternating-current voltage

between said pixel electrode and said common electrode, said pixel electrode and said common electrode are connected to an external control means by which the applied electric field is arbitrarily controlled according to a display pattern, two orientation films print-coated are formed directly or through insulating film on said electrode-formed substrate and said color-filter-formed substrate, respectively, the two orientation films are disposed opposite each other and with a predetermined clearance by a panel spacer, nematic liquid crystal is filled into said clearance while being anti-parallel oriented, and the active-element-side holding capacitance is varied to each of said color layers so as to compensate a difference in the sum of color-layer capacitance and liquid-crystal capacitance at each of the color layers (R, G, B) in the color filter.

4. An active matrix liquid-crystal display device, comprising:

an electrode-formed substrate which is composed of a drain signal electrode, a gate signal electrode, a pixel electrode and a common electrode to compose a pixel unit, and an active element;

a color-filter-formed substrate where no electrode is formed and a color filter layer of red (R), green (G) and blue (B) to color light transmitted therethrough is formed; and

a liquid-crystal layer sandwiched between said electrode-formed substrate and said color-filter-formed substrate;

wherein a plurality of said pixel electrode and said common

electrode on said electrode-formed substrate each are in unit pixel, and disposed parallel at predetermined intervals and alternately in a same layer or through insulating film, electric field substantially parallel to said electrode-formed substrate and said color-filter-formed substrate is applied to said liquid-crystal layer by applying an alternating-current voltage between said pixel electrode and said common electrode, said pixel electrode and said common electrode are connected to an external control means by which the applied electric field is arbitrarily controlled according to a display pattern, two orientation films print-coated are formed directly or through insulating film on said electrode-formed substrate and said color-filter-formed substrate, respectively, the two orientation films are disposed opposite each other and with a predetermined clearance by a panel spacer, nematic liquid crystal is filled into said clearance while being anti-parallel oriented, and a circuit to send electrical signal to each of the color layers (R, G, B) in the color filter is provided to make a difference in the central value of drain signal voltages for the respective color layers.

5. An active matrix liquid-crystal display device, according to claim 4, wherein:

the difference in the central value of drain signal voltages is set to satisfy the relation:

$$V_{BLUE}\ (V) = V_{RED}\ (V) - 0.2\ (V) = V_{GREEN} - 0.1\ (V)$$

where V_{BLUE}, V_{RED} and V_{GREEN} are the central values of drain voltage of blue, red and green, respectively.

6. An active matrix liquid-crystal display device, according to claim 4, wherein:

the resistivity Y ($\Omega \cdot$cm) of the color layers (R, G, B), and the difference X (V) between the central value of drain voltage at the red color layer and the central value of drain voltage at each of the color layers (R, G, B) is set to satisfy the relation:

$$Y = C \cdot X + D$$

where C and D are in the range of:

$$3 \times 10^{11} < C < 7 \times 10^{11}$$

$$0.5 \times 10^{11} < D < 1.0 \times 10^{11}$$

, and preferably,

$$C = 5 \times 10^{11}$$

$$D = 0.8 \times 10^{11}.$$

7. An active matrix liquid-crystal display device, comprising:

an electrode-formed substrate which is composed of a drain signal electrode, a gate signal electrode, a pixel electrode and a common electrode to compose a pixel unit, and an active element;

a color-filter-formed substrate where no electrode is formed and a color filter layer of red (R), green (G) and blue (B) to color light transmitted therethrough is formed; and

a liquid-crystal layer sandwiched between said electrode-formed substrate and said color-filter-formed substrate;

wherein a plurality of said pixel electrode and said common

electrode on said electrode-formed substrate each are in unit pixel, and disposed parallel at predetermined intervals and alternately in a same layer or through insulating film, electric field substantially parallel to said electrode-formed substrate and said color-filter-formed substrate is applied to said liquid-crystal layer by applying an alternating-current voltage between said pixel electrode and said common electrode, said pixel electrode and said common electrode are connected to an external control means by which the applied electric field is arbitrarily controlled according to a display pattern, two orientation films print-coated are formed directly or through insulating film on said electrode-formed substrate and said color-filter-formed substrate, respectively, the two orientation films are disposed opposite each other and with a predetermined clearance by a panel spacer, nematic liquid crystal is filled into said clearance while being anti-parallel oriented, and a circuit to send electrical signal to each of the color layers (R, G, B) in the color filter is provided to make a difference in the amplitude of drain signal voltages for the respective color layers.

ABSTRACT OF THE DISCLOSURE

Disclosed is an active matrix liquid-crystal display device, which has: an electrode-formed substrate which is composed of a drain signal electrode, a gate signal electrode, a pixel electrode and a common electrode to compose a pixel unit, and an active element; a color-filter-formed substrate where no electrode is formed and a color filter layer of red (R), green (G) and blue (B) to color light transmitted therethrough is formed; and a liquid-crystal layer sandwiched between the electrode-formed substrate and the color-filter-formed substrate; wherein the fieldthrough of respective color layers (R,G,B) of the color filter layer is equalized.

FIG. 1 PRIOR ART

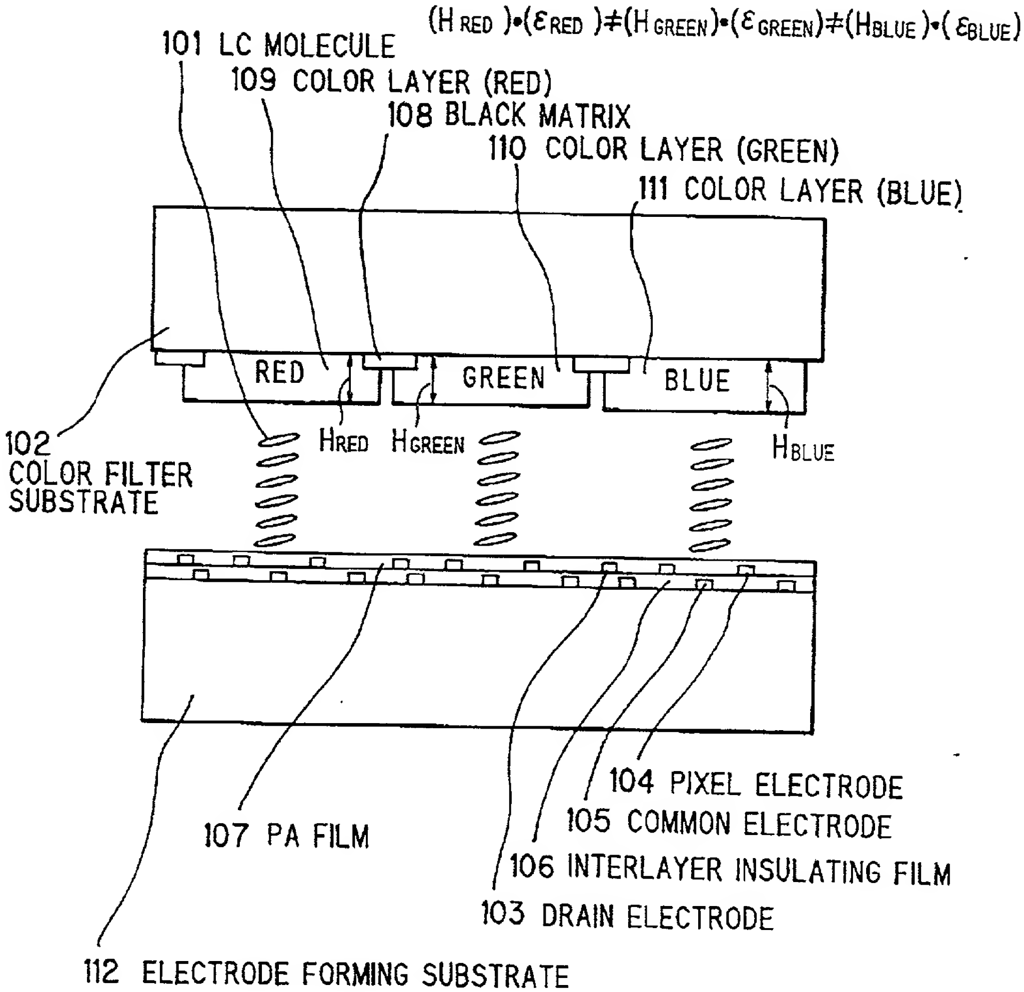


FIG.2 PRIOR ART

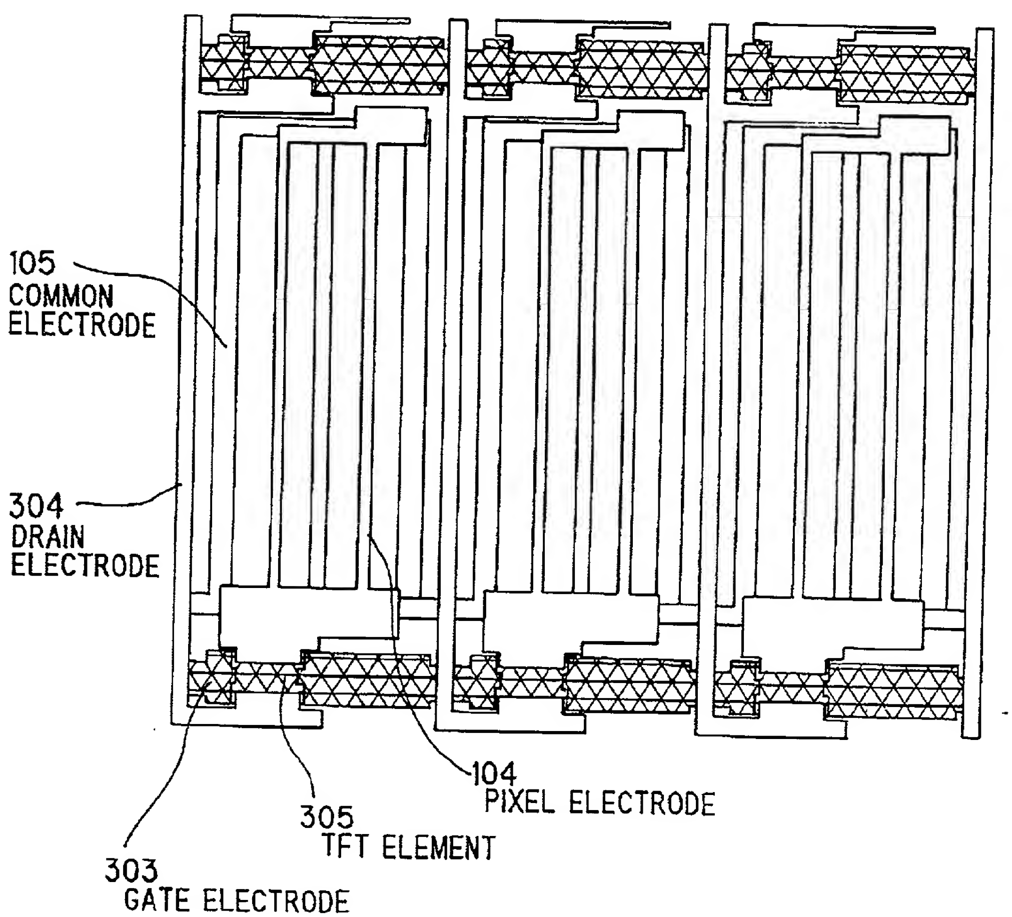
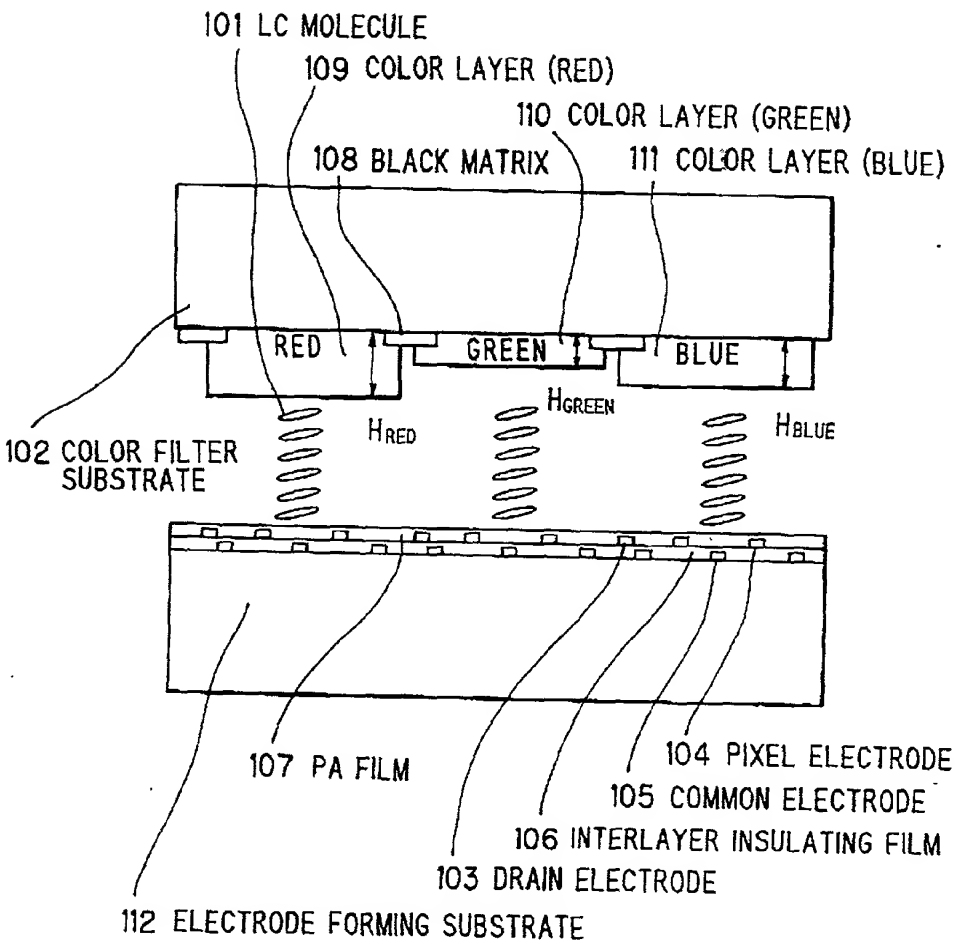


FIG.3



$$(H_{RED})\cdot(\varepsilon_{RED})=(H_{GREEN})\cdot(\varepsilon_{GREEN})=(H_{BLUE})\cdot(\varepsilon_{BLUE})$$

FIG.4

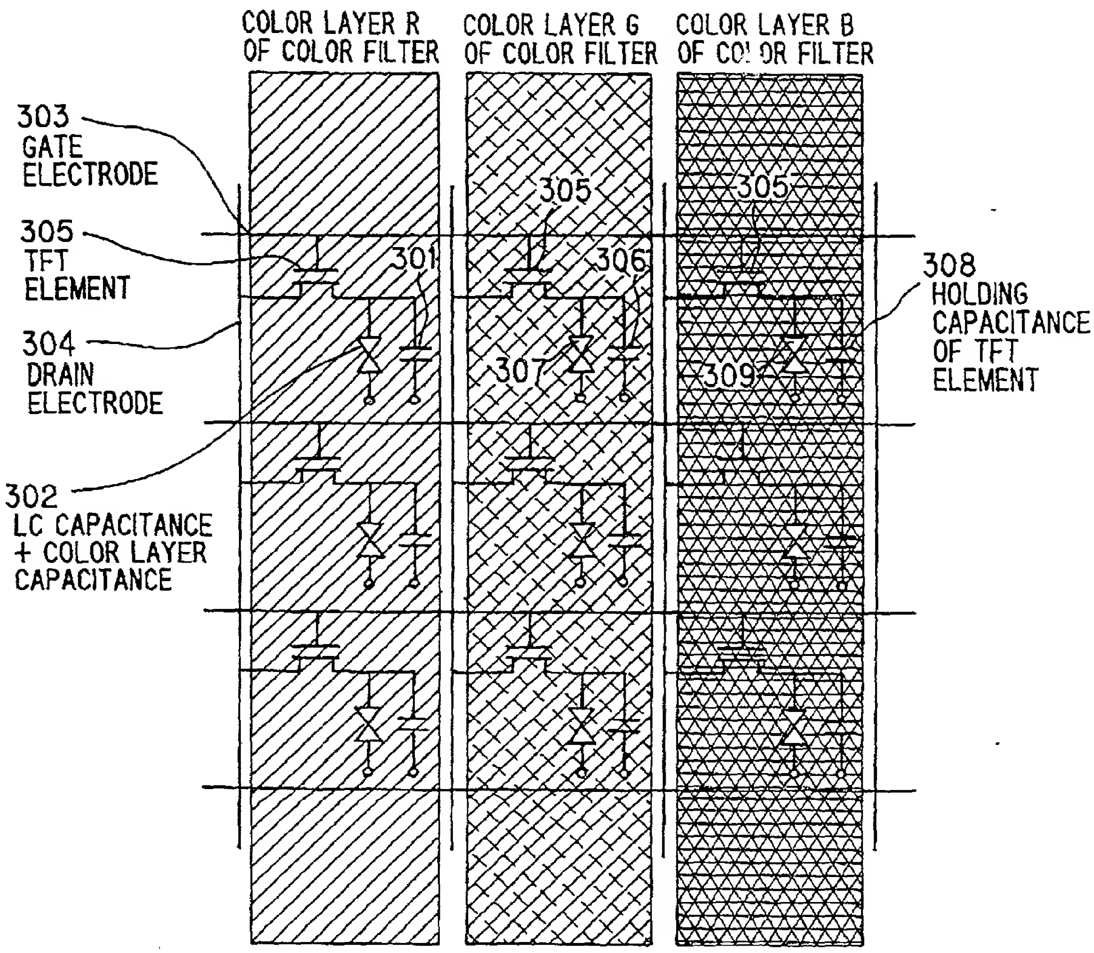
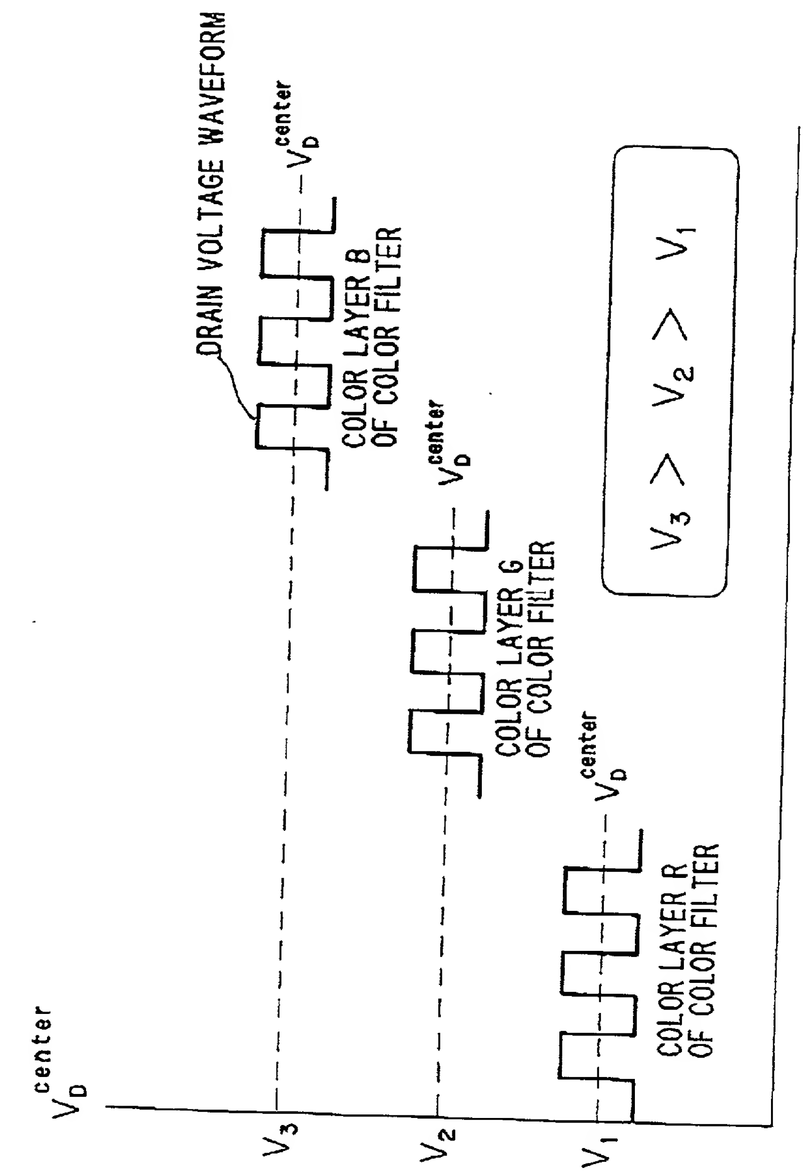
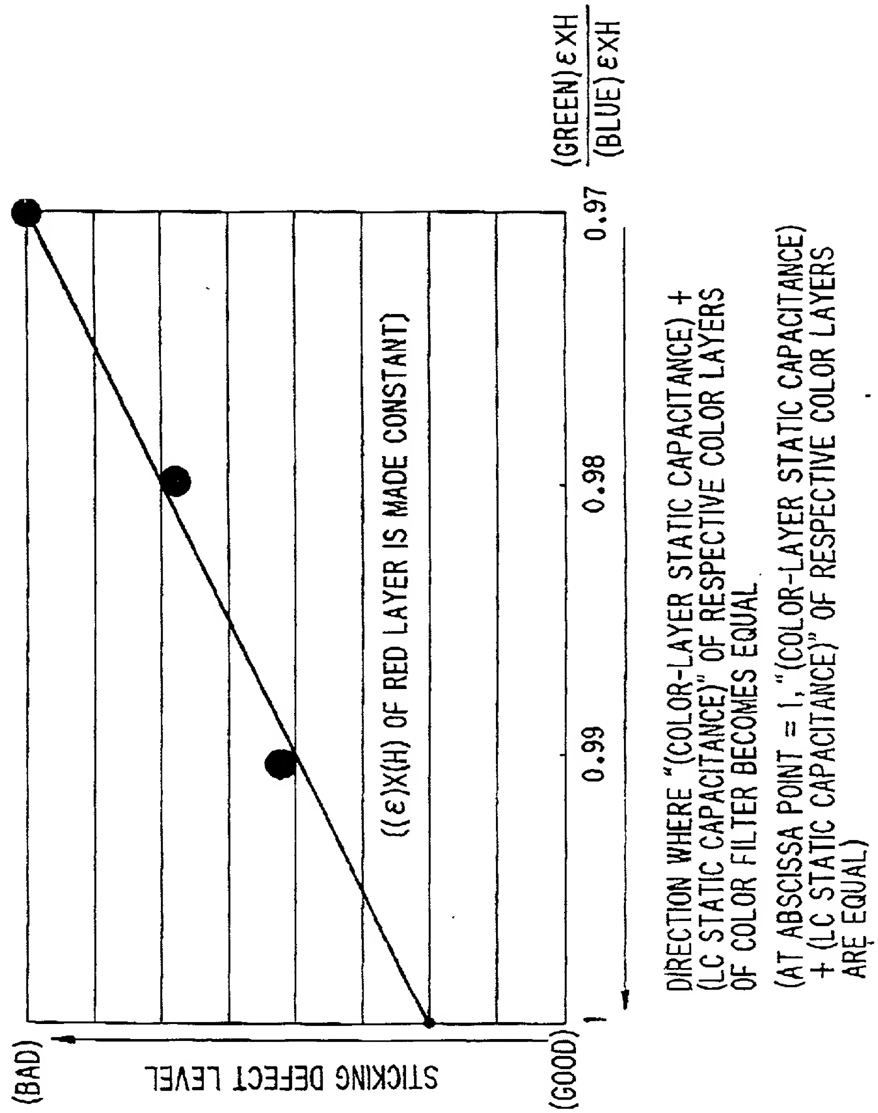

COLOR LAYER R
OF COLOR FILTER
COLOR LAYER G
OF COLOR FILTER
COLOR LAYER B
OF COLOR FILTER
303
GATE
ELECTRODE
305
TFT
ELEMENT
304
DRAIN
ELECTRODE
302
LC CAPACITANCE
+ COLOR LAYER
CAPACITANCE
301
305
306
307
305
309
308
HOLDING
CAPACITANCE
OF TFT
ELEMENT

FIG.5


DRAIN VOLTAGE WAVEFORM
V_D^{center}
COLOR LAYER B OF COLOR FILTER
V_D^{center}
COLOR LAYER G OF COLOR FILTER
V_D^{center}
COLOR LAYER R OF COLOR FILTER
V_D^{center}
V_3
V_2
V_1
$V_3 > V_2 > V_1$



(GREEN) εXH / (BLUE) εXH
0.97
0.98
0.99
1
(BAD)
STICKING DEFECT LEVEL
(GOOD)
((ε)X(H) OF RED LAYER IS MADE CONSTANT)
DIRECTION WHERE "(COLOR-LAYER STATIC CAPACITANCE) + (LC STATIC CAPACITANCE)" OF RESPECTIVE COLOR LAYERS OF COLOR FILTER BECOMES EQUAL
(AT ABSCISSA POINT = 1, "(COLOR-LAYER STATIC CAPACITANCE) + (LC STATIC CAPACITANCE)" OF RESPECTIVE COLOR LAYERS ARE EQUAL)

FIG.6

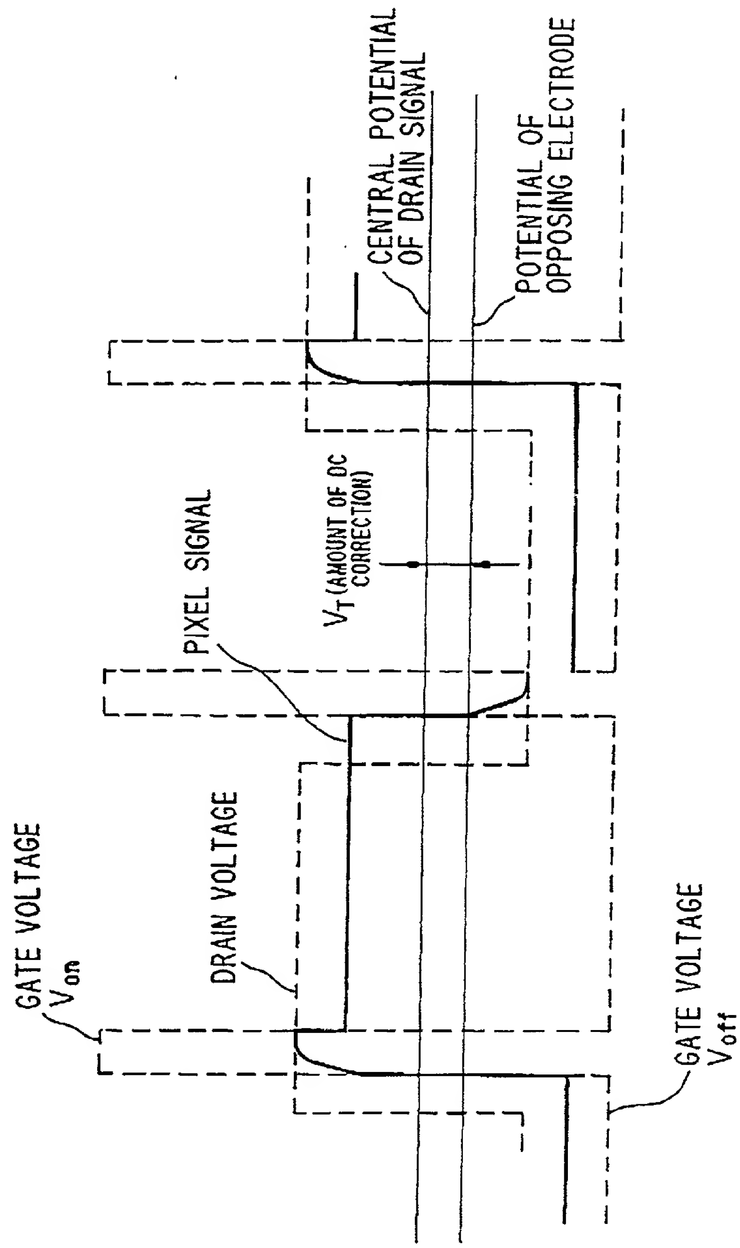
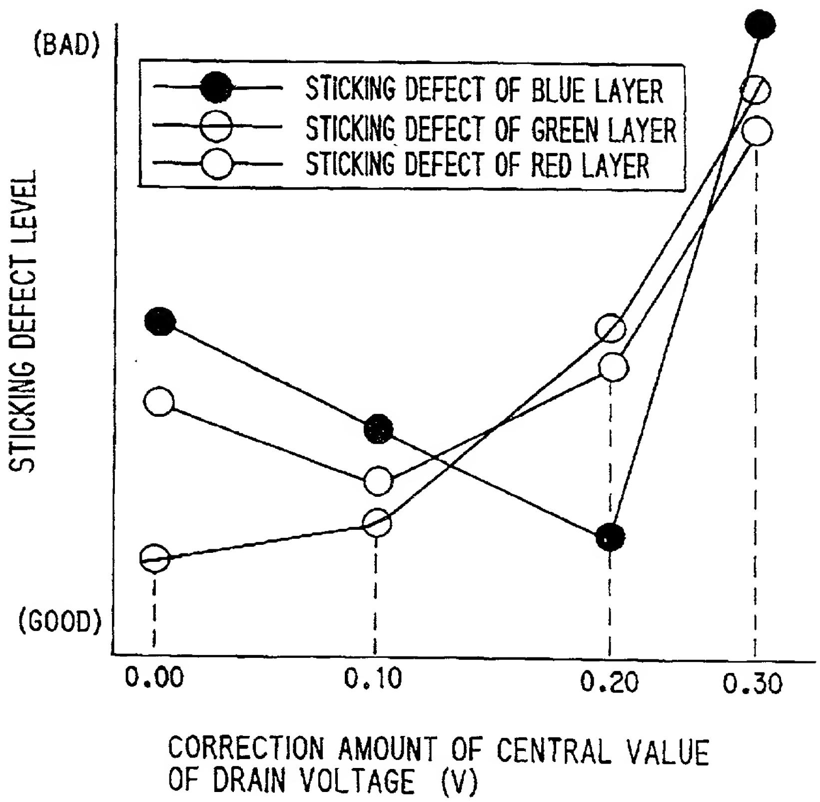

CENTRAL POTENTIAL
OF DRAIN SIGNAL
POTENTIAL OF
OPPOSING ELECTRODE
V_T (AMOUNT OF DC
CORRECTION)
PIXEL SIGNAL
DRAIN VOLTAGE
GATE VOLTAGE
V_{on}
GATE VOLTAGE
V_{off}

FIG. 7

FIG.8


(BAD)
(GOOD)
STICKING DEFECT LEVEL
STICKING DEFECT OF BLUE LAYER
STICKING DEFECT OF GREEN LAYER
STICKING DEFECT OF RED LAYER
0.00
0.10
0.20
0.30
CORRECTION AMOUNT OF CENTRAL VALUE
OF DRAIN VOLTAGE (V)

DECLARATION AND POWER OF ATTORNEY

As a below named inventor, I hereby declare that my residence, post office address and citizenship are as stated below next to my name: that I verily believe I am the original, first and sole inventor (if only one name is listed below) or a joint inventor (if plural names are listed below) of the subject matter claimed and for which a patent is sought in the application entitled:

"ACTIVE MATRIX LIQUID-CRYSTAL DISPLAY DEVICE"

which application is:
x the attached application
(for original application)

____ application Serial No. ________________.
filed ________________, and amended on
____
(for declaration not accompanying application)

that I have reviewed and understand the contents of the specification of the above-identified application, including the claims, as amended by any amendment referred to above; that I acknowledge my duty to disclose information of which I am aware which is material to the patentability of this application under 37 C.F.R. 1.56, that I hereby claim foreign priority benefits under Title 35, United States Code §119, §172 or §365 of any foreign application(s) for patent or inventor's certificate listed below and have also identified on said list any foreign application for patent or inventor's certificate on this invention having a filing date before that of the application on which priority is claimed:

Application Number	Country	Filing Date	Priority Claimed (yes or no)
328678/1997	Japan	November 28, 1998	Yes

I hereby claim the benefit of Title 35, United States Code §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in a listed prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge my duty to disclose any information material to the patentability of this application under 37 C.F.R. 1.56 which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

Application Serial No.	Filing Date	Status (patented, pending, abandoned)

I hereby appoint John H. Mion, Reg. No. 18,879; Donald E. Zinn, Reg. No. 19,046; Thomas J. Macpeak, Reg. No. 19,292; Robert J. Seas, Jr., Reg. No. 21,092; Darryl Mexic, Reg. No. 23,063; Robert V. Sloan, Reg. No. 22,775; Peter D. Olexy, Reg. No. 24,513; J. Frank Osha, Reg. No. 24,625; Waddell A. Biggart, Reg. No. 24,861; Robert G. McMorrow, Reg. No. 19,093; Louis Gubinsky, Reg. No. 24,835; Neil B. Siegel, Reg. No. 25,200; David J. Cushing, Reg. No. 28,703; John R. Inge, Reg. No. 26,916; Joseph J. Ruch, Jr., Reg. No. 26,577; Sheldon I. Landsman, Reg. No. 25,430; Richard C. Turner, Reg. No. 29,710; Howard L. Bernstein, Reg. No. 25,665; Alan J. Kasper, Reg. No. 25,426; Kenneth J. Burchfiel, Reg. No. 31,333; Gordon Kit, Reg. No. 30,764; Susan J. Mack, Reg. No. 30,951; Frank L. Bernstein, Reg. No. 31,484; Mark Boland, Reg. No. 32,197; William H. Mandir, Reg. No. 32,156; Scott M. Daniels, Reg. No. 32,562; Brian W. Hannon, Reg. No. 32,778 and Abraham J. Rosner, Reg. No. 33,276, my attorneys to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith, and request that all correspondence about the application be addressed to SUGHRUE, MION, ZINN, MACPEAK & SEAS, 2100 Pennsylvania Avenue, N.W., Washington, D.C. 20037-3202.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

Date November 25, 1998

First Inventor Kimikazu · MATSUMOTO
First Name · Middle Initial · Last Name

Residence Tokyo, Japan

Signature *Kimikazu Matsumoto* (seal)

Post Office Address c/o NEC Corporation
7-1, Shiba 5-chome, Minato-ku, Tokyo, Japan

Citizenship Japanese

Date November 25, 1998

Residence Tokyo, Japan

Citizenship Japanese

Second Inventor Shinichi NISHIDA
First Name Middle Initial Last Name

Signature Shinichi Nishida

Post Office Address c/o NEC Corporation
7-1, Shiba 5-chome, Minato-ku, Tokyo, Japan

Date November 25, 1998

Residence Tokyo, Japan

Citizenship Japanese

Third Inventor Hideo SHIBAHARA
First Name Middle Initial Last Name

Signature Hideo Shibahara

Post Office Address c/o NEC Corporation
7-1, Shiba 5-chome, Minato-ku, Tokyo, Japan

Date

Residence

Citizenship

Fourth Inventor
First Name Middle Initial Last Name

Signature

Post Office Address

Date

Residence

Citizenship

Fifth Inventor
First Name Middle Initial Last Name

Signature

Post Office Address

Date

Residence

Citizenship

Sixth Inventor
First Name Middle Initial Last Name

Signature

Post Office Address

Date

Residence

Citizenship

Seventh Inventor
First Name Middle Initial Last Name

Signature

Post Office Address